widespread decisions, such as how a group of primates decide where to travel after a rest period or how a flock of birds decides when to leave a foraging patch. "Unless all members decide on the same action, some will be left behind and will forfeit, at least temporarily, the advantages of group living," they write.

"Thus, in order to maintain group cohesion, social animals — like humans — have to make consensus decisions."

But, as in human consensus decisions, these often lead to a conflict of interest between group members, as individuals vary in their optimum preferences. Therefore, in order to reach a consensus, group members often have to compromise, thereby incurring a 'consensus cost'.

Consensus costs can be substantial: for example, in some circumstances they are sufficient to prevent a consensus from being reached, thereby causing groups to fragment.

The authors claim the new model shows that both equally shared consensus decisions and unshared decision making can evolve through, and be maintained by, individual selection. "An important part of the argument that renders the evolution of equally shared decisions possible is that individual members cannot predict with certainty what other group members are going to do," they write.

Essentially, it pays all individual members of a group to bluff, rather than communicating honestly about their readiness to compromise their own interests. So would-be selfish individuals cannot exploit other group members' readiness to compromise.

The most important conclusion of the model, the authors write, is that while, in principle, both equally shared and unshared decision making can evolve through individual selection, equally shared decisions can evolve under a much wider variety of conditions.

So democracy, on balance, might have a deeper base than previously realised.

Q & A

Armand Leroi

Armand Marie Leroi is Reader in Evolutionary Developmental Biology at Imperial College London. He did his PhD with Michael Rose at the University of California, Irvine and his post-doctoral work with Scott Emmons at Albert Einstein College of Medicine, New York. There he began to work on the evolution and development of growth in nematodes, and still does — but he has also forayed into computational embryology, transmissible cancers and cultural evolution. His popular book, Mutants: On the Form, Variety and Errors of the Human Body *(2004) was turned into a television series. Since then, he has written or fronted several other television programs, and has received awards for doing so.*

How did you get into science? I was a boy naturalist. I spent part of my childhood in South Africa, a country in which the natural world is richly present and endlessly seductive. There were sacred ibises and hoopoes on the lawn, chameleons in the Proteas and a little stream full of *Xenopus* and crabs that one could follow (if one didn't have to be home for dinner) to the great Limpopo itself. And there was a bag of sea-shells that my parents had picked up on their travels. One day an amateur collector came to my school and identified them for me. That was my discovery of the Linnean binomial system; I was 11. Since then, my deepest intellectual impulses have been to determine the logic, the order, that lies beneath the apparent chaos that the natural world presents us with.

Do you have a scientific hero? Aristotle. His genius was simply to invent biology. He was the first to go down to the shore, pick up a snail, ask "what's inside?" — and then cut it up to find out. He did that to around 50 species, wrote the results down, and built a theory of development, physiology and taxonomy from them. To read him is to enter a parallel science, as beautiful and logical as our own, sometimes familiar, sometimes unutterably strange, but always unmistakably the product of a rational, querying, sceptical, systematizing, scientific mind.

What paper has most influenced you? That would be the 1993 paper from Cynthia Kenyon's group reporting the discovery that insulin receptor mutations increase longevity in worms (A *C. elegans* mutant that lives twice as long as wild type. Nature *366*, 461–464). Before this paper it was dogma, at least among evolutionary geneticists, that traits such as longevity and growth were intrinsically polygenic and could only, should only, be studied by quantitative genetics. This was a counsel of despair. Inspired, in part, by the clarity of Kenyon's work, I began to study body size mutations in worms, and continue to do so. Of course, the controls of longevity and growth do, indeed, ramify throughout almost every part of a creature's physiology and structure. So they're not as simple as the vulva. So what?

What paper will influence you? The classical problem of growth is the mystery of how a creature's organs know what size they should be. Last year, a paper was published that gave a remarkably clear and simple account of how compartment size is controlled in the *Drosophila* embryo. The author was Joe Parker; the lab was Peter Lawrence's (though, characteristically, his name doesn't appear on the paper); the journal was a good one: Control of compartment size by an EGF Ligand from neighbouring cells. Curr. Biol. *16*, 2058–2065. I think it's a milestone.

What important questions remain to be answered in your field? I can think of two. The first is: can we predict the course of organic evolution in the long term? The short term is easy: that's just the breeder's equation. But understanding the *longue durée* requires a theory that predicts what phenotypes mutation will produce. I am, of course, talking about 'the correlation of parts', 'developmental constraints', 'mutational bias', the 'integration of development with evolution', 'the real reason pigs can't fly' — every generation since Darwin has considered, and failed to solve, the problem, though they've usually given it a new name.

The second question is rather like the first: can we predict the course of cultural evolution in the long term? (One might add: or even in the short term?) Darwin saw the analogy between cultural and organic evolution; theoretical population geneticists worked out the mathematics of the transmission of cultural traits years ago. Despite this, the field really didn't take off. I think it is taking off now. Culture is the New World of evolutionary science. To be sure, anthropologists discovered it long ago, but rather like Vikings in America, they never made much of what they found.

Do you think that ethics and politics have a role in science? Most scientists are funded by taxpayers and so should be bound by the laws, and sensitive to the mores, of the democratic societies in which they live. Sure. But I am haunted by the thought that had not Vesalius robbed graves for corpses, and thereby defied the State, the Church and the mob, we would have no human anatomy. Who among us would do as he did?

You do television. How do the worlds of science and media compare? Referees of scientific manuscripts may, on occasion, be exasperatingly obtuse or cruelly cutting, but they rarely stray into the personal. Not so TV critics who have variously labelled me (in descending order of approbation): "steely gazed", "sexily soulful," "sleek/slap/shiny-headed" and "smug and slightly seedy". And that just covers the letter "S". All you can do is sigh and pour yourself a scotch.

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Humboldt expansion

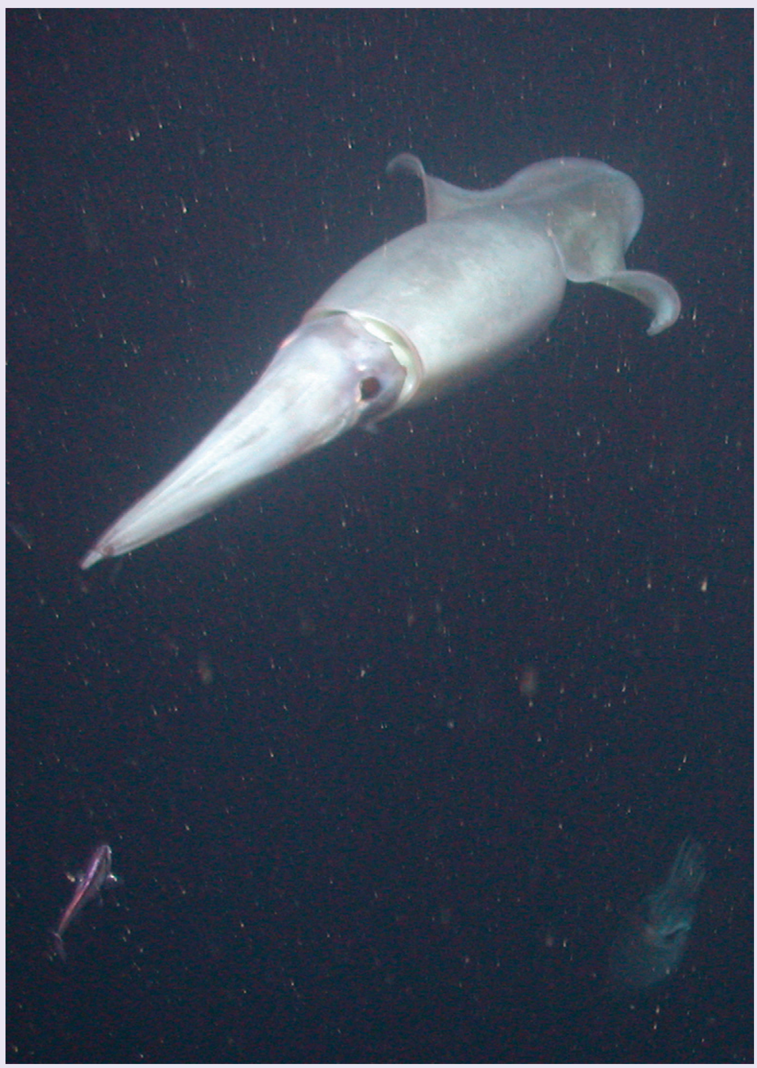
A major Pacific marine predator has expanded its range substantially in recent years raising fears amongst ocean conservation and sustainability researchers about its ecological impact.

A unique 16-year time series of deep video surveys in Monterey Bay, California, reveals that the Humboldt squid has increased its perennial geographical range in the eastern North Pacific by invading the waters off central California.

This expansion coincides with changes in climate-linked oceanographic conditions and a reduction in competing top predators. It also coincides with a decline in the abundance of Pacific hake, the most important commercial groundfish species off western North America.

The Humboldt squid is a large, aggressive, abundant and highly mobile squid. It can reach a length of more than two metres and weigh 50 kg and, remarkably, achieve these sizes very rapidly as the adults are thought to be very short lived.

Its geographical range is centred in the eastern equatorial Pacific. From these warm waters,



Invader: The Humboldt squid (*Dosidicus gigas*) appears to have expanded its range in the eastern Pacific, with a decline in commercially important hake stocks. (Image: © 2003 MBARI.)